User's Guide
SLUU270 – June 2007

Using the bq2000EVM

1 Introduction

This user's guide describes the bq2000EVM EVM (an evaluation module for the bq2000 and bq2000T). The EVM provides a convenient method for evaluating the performance of a charge management solution for portable applications using either the bq2000 or bq2000T. A complete and tested charger is presented. The charger is designed to deliver up to 1.0A of continuous output current. The DV2000S1 is shipped with a programmed default charging current of 1.0A. Refer to the bq2000/bq2000T data sheet (literature ID "bq2000") prior to using this EVM for detailed information on the bq2000 or bq2000T device.

1.1 Device Background

The bq2000 is a programmable, monolithic IC for fast-charge management of nickel cadmium (NiCd), nickel metal-hydride (NiMH), or lithium-ion (Li-Ion) batteries in single or multi-chemistry applications. The bq2000 detects the battery chemistry and proceeds with the optimal charging and termination algorithms. This process eliminates undesirable undercharged or overcharged conditions and allows accurate and safe termination of fast charge. Depending on the chemistry, the bq2000 provides a number of charge termination criteria. The bq2000 can terminate charge based on peak voltage detection (PVD) for NiCd and NiMH batteries, minimum charging current for Li-Ion batteries, maximum temperature, or maximum charge time. For safety, the bq2000 inhibits fast charge until the battery voltage and temperature are within user-defined limits. If the battery voltage is below the low-voltage threshold, the bq2000 uses trickle-charge to condition the battery. For NiMH batteries, the bq2000 provides an optional top-off charge to maximize the battery capacity. The integrated high-frequency comparator allows the bq2000 to be the basis for a complete, high-efficiency power-conversion circuit for both nickel-based and lithium-based chemistries.

1.2 EVM Differences

In addition to this bq2000EVM EVM, there are also DV2000S1 and DV2000TS1 EVMs available for evaluating the performance of the bq2000 or bq2000T. The DV2000S1/TS1 boards make use of through-hole devices while the bq2000EVM board was later developed to utilize all surface-mount devices and reduce the physical size of the EVM. Both EVMs provide complete evaluation environments for the bq2000/bq2000T, support up to 4 Li-Ion or 10 NiCd/NiMH cells, are user-programmable for other cell counts, and can operate with or without a charge top-off period. To correctly operate each EVM, consult its corresponding user's guide.

1.3 Performance Specification Summary

Specification	Min	Typ	Max	Unit
Input DC voltage, V(DC+) – V(DC–)	10		25	V
Battery voltage, V(BAT+) – V(BAT–)			18	V
Battery charge current, I(BAT+)			1.0	A
Thermistor voltage, V(TS)	0		5	V

2 Setup and Configuration

This section describes the jumper connections on the bq2000EVM along with the resulting operation. It describes the different ways this EVM can be used with a variety of battery packs.

2.1 Connection Descriptions

Jumper Designator	Description
J1: DC+	DC input positive voltage from external supply
J1: DC–	DC input ground
J2: BAT+	Positive terminal of the battery or battery pack
J2: BAT–	Negative terminal of the battery or battery pack
J2: TS	Thermistor connection
J2: BAT–	Negative terminal of the battery or battery pack, used for thermistor connection
J3: C/4, 320, Y	Place jumper here for a C/4 charge rate, 320 minute timeout, top-off mode selected
J3: C/4, 320, N	Place jumper here for a C/4 charge rate, 320 minute timeout, top-off mode not selected
J3: C/3, 240, Y	Place jumper here for a C/3 charge rate, 240 minute timeout, top-off mode selected
J3: C/3, 240, N	Place jumper here for a C/3 charge rate, 240 minute timeout, top-off mode not selected
J3: C/2, 160, Y	Place jumper here for a C/2 charge rate, 160 minute timeout, top-off mode selected
J3: C/2, 160, N	Place jumper here for a C/2 charge rate, 160 minute timeout, top-off mode not selected
J3: C, 80, Y	Place jumper here for a C charge rate, 80 minute timeout, top-off mode selected
J3: C, 80, N	Place jumper here for a C charge rate, 80 minute timeout, top-off mode not selected
J3: USER, Y	Place jumper here to select a user-defined charge rate and timeout, uses top-off mode
J3: USER, N	Place jumper here to select a user-defined charge rate and timeout, no top-off mode
J4: Top off Y	Place jumper between Y and COM to select top-off mode
J4: Top off COM	Connect to top-off Y or top-off N
J4: Top off N	Place jumper between N and COM to not use top-off mode
J5: USER	Place jumper here for a user-defined NiCd/NiMH cell count
J5: 10	Place jumper here when using a battery pack of 10 NiCd/NiMH cells in a series configuration
J5: 8	Place jumper here when using a battery pack of 8 NiCd/NiMH cells in a series configuration
J5: 6	Place jumper here when using a battery pack of 6 NiCd/NiMH cells in a series configuration
J5: 5	Place jumper here when using a battery pack of 5 NiCd/NiMH cells in a series configuration
J5: 4	Place jumper here when using a battery pack of 4 NiCd/NiMH cells in a series configuration
J6: 4	Place jumper here when using a battery pack of 4 Li-Ion cells in a series configuration
J6: 3	Place jumper here when using a battery pack of 3 Li-Ion cells in a series configuration
J6: 2	Place jumper here when using a battery pack of 2 Li-Ion cells in a series configuration
J6: 1	Place jumper here when using a battery pack of 1 Li-Ion cells in a series configuration

2.2 Board Setup

The bq2000EVM can be configured as described below.

Number of Cells Selection (JP5, JP6): These jumpers select the number of cells for either Li-Ion or NiCd/NiMH batteries. These jumpers should be changed only if the battery is absent or if the DC supply is not connected to the board. Only one jumper should be placed on a J5 or J6 connection for proper circuit configuration.

Note that there are two *USER* defined connections provided on J5. This connection can be configured for NiCd/NiMH or Li-Ion cell counts other than what are predefined on the bq2000EVM. Configuration is accomplished by placing an appropriate resistor in the USER Y or N position according to the desired battery pack voltage.

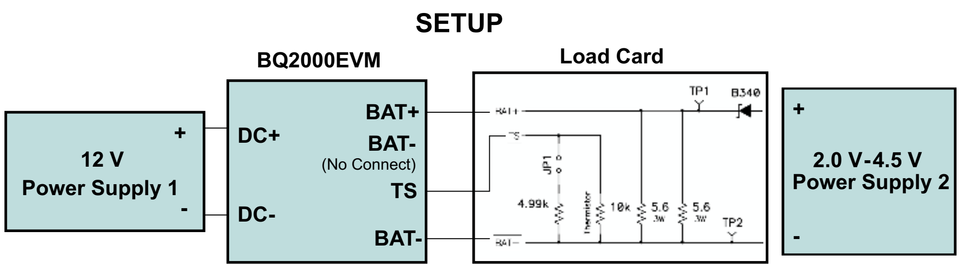
2.3 Setup Procedure – Testing With a Battery Pack

The following procedure outlines how to set up the bq2000EVM when charging a battery pack:

1. Configure the bq2000EVM for the appropriate number and type of cells by placing a single jumper on one of the J5 or J6 connection points.
2. Place a jumper between J4's COM and YES to utilize the bq2000's top-off mode or between COM and NO to not use the top-off mode.
3. Place one jumper on one of the J3 connection points to select a charge rate and timeout duration. If top-off mode is being used, only a J3 connection labeled "Y" should be used. A J3 connection labeled "N" should be used if top-off mode is not being used.
4. Connect the thermistor between TS and the lower BAT–. If using a thermistor is not desired, a 10-kΩ resistor can be connected between TS and BAT–.
5. Connect the battery pack to BAT+ and BAT–.
6. Connect the charging supply to J1 while ensuring that it falls within the bq2000EVM's recommended DC operating range.

2.4 Setup Procedure – Testing Without a Battery Pack

Sometimes it is beneficial to test a battery charger without charging an actual battery due to the long time needed to charge/discharge battery packs. An ideal substitute for a battery is a four-quadrant power supply that can both sink and source current. If a four-quadrant power supply is unavailable, the load card shown below can be used in parallel with a standard two-quadrant power supply. The load card as shown is designed to charge a one-cell lithium-ion battery at 1A constant current charge.



1. Configure the bq2000EVM for the appropriate number and type of cells by placing a single jumper on one of the J5 or J6 connection points.
2. Place a jumper between J4's COM and YES to utilize the bq2000's top-off mode or between COM and NO to not use the top-off mode.
3. Place one jumper on one of the J3 connection points to select a charge rate and timeout duration. If top-off mode is being used, only a J3 connection labeled "Y" should be used. A J3 connection labeled "N" should be used if top-off mode is not being used.
4. Connect the load card as shown above. A 10-kΩ thermistor or 10-kΩ resistor can be added to the load card for convenience. The JP1 header and 4.99-kΩ resistor are added to demonstrate the temperature sensing feature of the bq2000EVM. When the jumper is removed, the EVM will charge as normal. Installing the jumper simulates an over-temperature condition and the charger will turn off.
5. Connect the second power supply to the load card as shown. The series diode is added to protect the power supply from sinking current and potential damage. Turn power supply two on so that it is within the voltage range set in step one (4.2V/cell if simulating a lithium-ion battery is desired, or 1.2V/cell if a nickel-based battery is desired).
6. Connect the charging supply to J1 while ensuring that it falls within the bq2000EVM's recommended DC operating range.

The load card allows a two-quadrant power supply to be used because it sinks current to BAT– through the shunt resistors. The above load card is designed for charging a single lithium-ion battery at 1A constant current. The charge range for a one-cell lithium-ion battery is 2.7 V to 4.2 V. Whenever the voltage on power supply two is less than 2.7 V, the bq2000EVM will be off and power supply two will source current through the shunt resistors. The charging algorithm for the bq2000EVM depends on the charge voltage that it sees on BAT+. As the voltage on power supply two is increased to within the set charge range of the bq2000EVM, the bq2000EVM will turn on into constant current mode and will source its set charge current (1A) into the load card. As the voltage provided by power supply two is increased, it will source enough current into the load card such that:

$V_{ps2} = R_{load} \times (I_{ps2} + I_{charge})$, where I_{charge} is the constant current charge sourced by the bq2000EVM, I_{ps2} is the current sourced by power supply two, R_{load} is the parallel resistance between BAT+ and BAT–, and V_{ps2} is the voltage on power supply two.

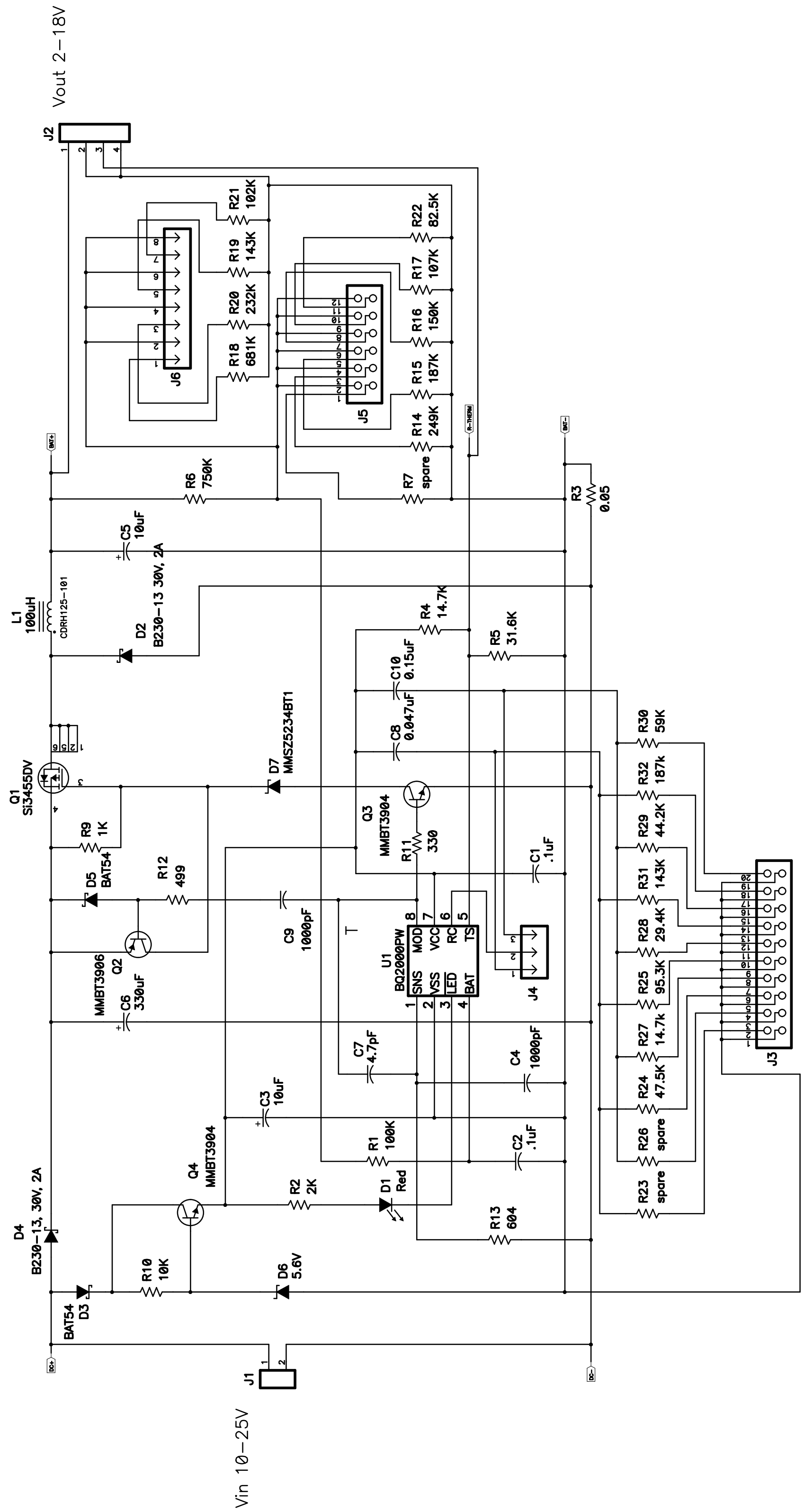
Once the voltage on power supply two goes above the termination point set on the bq2000EVM, the bq2000EVM will shut off and all current will be sourced by power supply two. To design a load card for an arbitrary battery pack, the following procedure can be used.

1. Determine the minimum (V_{min}) and maximum (V_{max}) charging voltages for the desired battery pack.
2. Determine the desired constant current charge (I_{chg})
3. Calculate the resistance (R_{load}) needed between BAT+ and BAT– by the following equation:

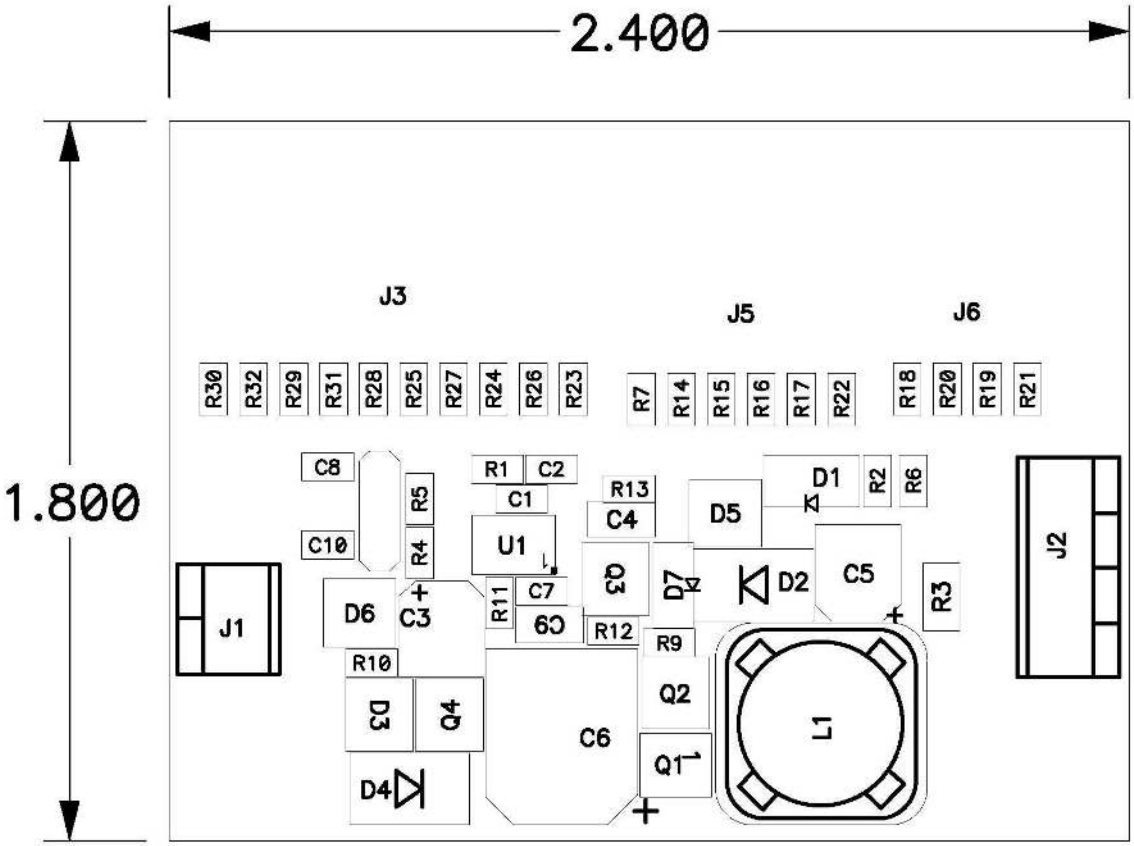
   $R_{load} = V_{min} / I_{chg}$
4. Calculate the power that will be dissipated by the shunts resistance (P_{shunt}):

   $P_{shunt} = V_{max}^2 / R_{load}$
5. Choose a combination of parallel resistors that meet the equivalent resistance and overall power dissipation rating needed to satisfy the above equations. **NOTE: Make sure power resistors are heat sunk properly to handle the amount of power to avoid overstressing the components.**

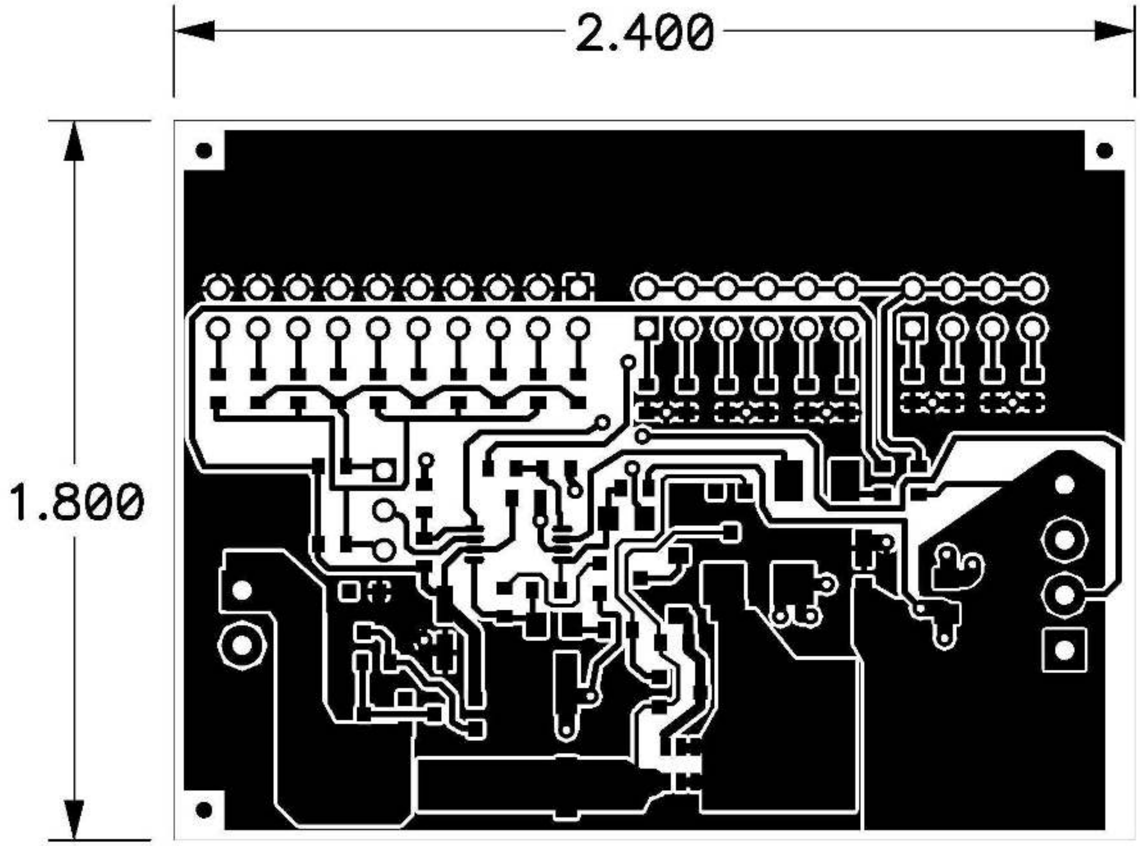
3 Schematic


Vout 2−18V
J2
R21 102K
R19 143K
R20 232K
R18 681K
J6
R22 82.5K
R17 107K
R16 150K
R15 187K
R14 249K
J5
R7 spare
R6 750K
R3 0.05
C5 10uF
L1 100uH
CDRH125-101
D2 B230−13 30V, 2A
R4 14.7K
R5 31.6K
C10 0.15uF
C8 0.047uF
Q1 Si3455DV
D7 MMSZ5234BT1
Q3 MMBT3904
R11 330
R9 1K
D5 BAT54
R12 499
C1 .1uF
C9 1000pF
U1 BQ2000PW
SNS VSS LED BAT MOD VCC RC TS
J4
Q2 MMBT3906
C6 330uF
C7 4.7pF
C4 1000pF
C3 10uF
R1 100K
C2 .1uF
Q4 MMBT3904
R2 2K
D1 Red
R13 604
D4 B230−13, 30V, 2A
R10 10K
D6 5.6V
D3 BAT54
J1
Vin 10−25V
R30 59K
R32 187k
R29 44.2K
R31 143K
R28 29.4K
R25 95.3K
R27 14.7k
R24 47.5K
R26 spare
R23 spare
J3

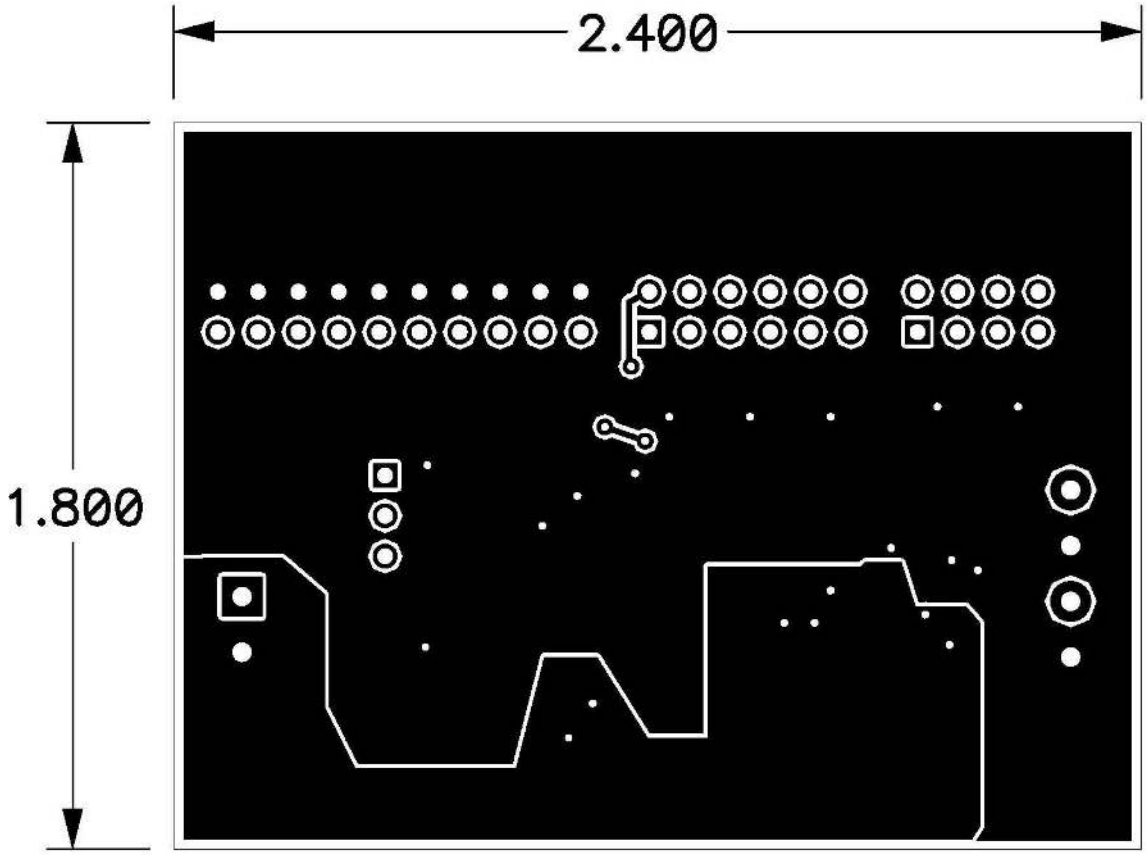
4 Physical Layouts



Top Assembly



Layer 1



Layer 2

5 Bill of Materials

Table 1. HPA250A Bill of Materials

Count	RefDes	Value	Description	Size	Part Number	MFR
2	C1, C2	0.1µF	Capacitor, Ceramic, X7R, 0.1 µF	0603	{std}	
1	C10	0.15µF	Capacitor, Ceramic, X7R, 0.15 µF, 16V	0603	{std}	
2	C3, C5	10µF	Capacitor, Aluminum, 10µF, 25V, 20%	0.177 × 0.177	EEV-FK1E100R	Panasonic
2	C4, C9	1000pF	Capacitor, Ceramic, 1000pF, 50V, X7R	0805	{std}	{std}
1	C6	330µF	Capacitor, Aluminum, SM, 330µF, 25V, 0.16Ω (FK series)	8 × 10 mm	EEV-FK1E331P	Panasonic
1	C7	4.7pF	Capacitor, Ceramic, 4.7pF, 50V, NPO	0603	{std}	{std}
1	C8	0.047µF	Capacitor, Ceramic, X7R, 0.047µF, 25V	0603	{std}	
1	D1	Red	Diode, LED, Red, 1.7V, 40mcd, SM	1210	SML-LX2832SRC-TR	Lumex
2	D2, D4	B230-13 30V, 2A	Diode, Schottky, 2A, 30V	SMB	B230-13	Diodes, Inc.
2	D3, D5	BAT54	Diode, Schottky, 200mA, 30V	SOT23	BAT54	Vishay-Liteon
1	D6	5.6V	Diode, Zener, 5.6V, 350mW	SOT23	BZX84C5V6T	Diodes, Inc.
1	D7	MMSZ5234BT1	Diode, Zener, 6.2V, 500mW	SOD-123	MMSZ5234BT1	On Semi
1	J1		Terminal block, 2pin, 6A, 3,5 mm	0.27 × 0.25"	ED1514	OST
1	J2		Terminal block, 4pin, 6A, 3,5 mm	0.55 × 0.25"	ED1516	OST
1	J3		Header, 2x10pin, 100mil spacing (36-pin strip)	0.100 × 10 × 2"	PTC36DAAN	Sullins
1	J4		Header, 3pin, 100mil spacing, (36-pin strip)	0.100 × 3"	PTC36DAAN	Sullins

Table 1. HPA250A Bill of Materials (continued)

Count	RefDes	Value	Description	Size	Part Number	MFR
1	J5		Header 2x6 pin, 100mil spacing (36-pin strip)	0.100 × 2 × 6"	PTC36DAAN	Sullins
1	J6		Header 2x4 pin, 100mil spacing (36-pin strip)	0.20 × 0.40	PTC36DAAN	Sullins
1	L1	100µH	Inductor, SMT, 100µH, 1.3A, 160mΩ	0.472 sq	CDRH125-101	Sumida
1	Q1	Si3455DV	MOSFET, Pch, –30V, 2.3A, 190mΩ	Micro6	Si3455DV	Vishay-Liteon
1	Q2	MMBT3906	Bipolar, PNP, 40V, 200mA, 0.22W	SOT23	MMBT3906-7	On Semi
2	Q3, Q4	MMBT3904	Bipolar, NPN, 40V, 200mA, 250mW	SOT23	MMBT3904	Fairchild
1	R1	100kΩ	Resistor, Chip, 100kΩ, 1/16W, 1%	0603	Std	Std
1	R11	330Ω	Resistor, Chip, 330Ω, 1/16W, 1%	0603	Std	Std
1	R12	499Ω	Resistor, Chip, 499Ω, 1/16W, 1%	0603	Std	Std
1	R13	604Ω	Resistor, Chip, 604Ω, 1/16W, 1%	0603	Std	Std
1	R14	249kΩ	Resistor, Chip, 249kΩ, 1/16W, 1%	0603	Std	Std
2	R15, R32	187kΩ	Resistor, Chip, 187kΩ, 1/16W, 1%	0603	Std	Std
1	R16	150kΩ	Resistor, Chip, 150kΩ, 1/16W, 1%	0603	Std	Std
1	R17	107K	Resistor, Chip, 107kΩ, 1/16W, 1%	0603	Std	Std
1	R18	681kΩ	Resistor, Chip, 681kΩ, 1/16W, 1%	0603	Std	Std
2	R19, R31	143kΩ	Resistor, Chip, 143kΩ, 1/16W, 1%	0603	Std	Std
1	R2	2kΩ	Resistor, Chip, 2kΩ, 1/16W, 1%	0603	Std	Std
1	R20	232kΩ	Resistor, Chip, 232kΩ, 1/16W, 1%	0603	Std	Std
1	R21	102kΩ	Resistor, Chip, 102kΩ, 1/16W, 1%	0603	Std	Std
1	R22	82.5kΩ	Resistor, Chip, 82.5kΩ, 1/16W, 1%	0603	Std	Std
1	R24	47.5kΩ	Resistor, Chip, 47.5kΩ, 1/16W, 1%	0603	Std	Std
1	R25	95.3kΩ	Resistor, Chip, 95.3kΩ, 1/16W, 1%	0603	Std	Std
1	R27	14.7kΩ	Resistor, Chip, 14.7kΩ, 1/16W, 1%	0603	Std	Std
1	R28	29.4kΩ	Resistor, Chip, 29.4kΩ, 1/16W, 1%	0603	Std	Std
1	R29	44.2kΩ	Resistor, Chip, 44.2kΩ, 1/16W, 1%	0603	Std	Std
1	R3	0.05Ω	Resistor, Chip, 0.05Ω, 1/10W, 1%	0805	Std	Std
1	R30	59kΩ	Resistor, Chip, 59kΩ, 1/16W, 1%	0603	Std	Std
1	R4	14.7kΩ	Resistor, Chip, 14.7kΩ, 1/16W, 1%	0603	Std	Std
1	R10	10kΩ	Resistor, Chip, 10kΩ, 1/16W, 1%	0603	Std	Std
1	R5	31.6kΩ	Resistor, Chip, 31.6kΩ, 1/16W, 1%	0603	Std	Std
1	R6	750kΩ	Resistor, Chip, 750kΩ, 1/16W, 1%	0603	Std	Std
0	R7, R23, R26	spare	Resistor, Chip, Ohms, 1/16W, 1%	0603	Std	Std
1	R9	1kΩ	Resistor, Chip, 1kΩ, 1/16W, 1%	0603	Std	Std
1	U1	BQ2000PW	IC, Fast Charge, Multi-chemistry	TSSOP-8	BQ2000PW	TI
1	Circuit board	HPA250	Circuit board		HPA250	Any
1	RT1		Thermister, 10kΩ	0.095 x 1.150 In	NTC103AT	Semitec

Notes:
1. These assemblies are ESD sensitive, ESD precautions shall be observed.
2. These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.
3. These assemblies must comply with workmanship standards IPC-A-610 Class 2.
4. Ref designators marked with an asterisk ('**') cannot be substituted. All other components can be substituted with equivalent MFG's components.
5. After testing RT1 is taped to the bottom of UUT with ESD tape.

6 References

1. bq2000 data sheet, http://focus.ti.com/lit/ds/symlink/bq2000.pdf
2. Using the bq2000/T to Control Fast Charge, http://focus.ti.com/lit/an/slua064b/slua064b.pdf

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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 10 V to 25 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 50°C. The EVM is designed to operate properly with certain components above 50°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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